physics update

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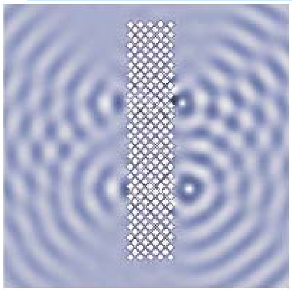
Negative refraction in water. The possibility of negatively refracted light—for which both the permittivity and permeability are negative—was postulated in 1967 and experimentally realized in 2000. (For more, see the article by John Pendry and David Smith in PHYSICS TODAY, June 2004, page 37.) The phenomenon has been exploited to create convergent flat lenses, usually made of so-called metamaterials, that beat the diffraction limit. Lensing effects have also been seen for negatively refracted acoustic waves. Recent theoretical work has begun to explore the phenomenon for liquid surface waves, and a team of researchers in France and the UK has now studied checkerboard lenses—arrays of square barriers in which either their edges or their vertices nearly touch. The team's analysis revealed that at certain frequencies, concentric surface waves can be refocused beyond such lenses; those results were confirmed with simulations like the one shown here for two wave disturbances impinging on an array of 8.4-mm squares with nearly touching edges. The researchers say their analysis can also apply to electromagnetic waves propagating in square arrays of infinite-conductivity obstacles, to certain shear waves in elastic media with square-shaped cracks, and possibly to ultrasound tomography. (M. Farhat et al., *Phys. Rev. E*, in press.) —SGB



The *Wilkinson Microwave Anisotropy Probe* collaboration has released its analysis (*WMAP* V) of five years of data from the orbiting satellite, which was launched in 2001. The results appear in seven papers available at http://wmap.gsfc.nasa.gov. *WMAP* measures the tiny point-to-point fluctuation of the cosmic microwave background's 2.7-K blackbody temperature and its even tinier polarization. The CMB is a snapshot of the cosmos when it first became transparent with the cooling of the opaque primordial plasma half a million years after the Big Bang. *WMAP* V brings no surprises, but it sharpens the "concordance" picture painted by the three-year data (*WMAP* III, see PHYSICS TODAY, May 2006, page 16) and complementary cosmological observation. *WMAP* V's significantly better delineation of the third acoustic peak in the power spectrum of the temperature fluctuations now shows the expected effect of the three species of light neutrinos that cosmologists believe to have decoupled from the plasma about a minute after the Big Bang. That confirms the existence of a cosmic background of neutrinos that have been redshifted to such low energy in the present universe that they cannot be detected directly. The data also address epochs much later than the first moment of cosmic transparency. The neutral hydrogen that first rendered the cosmos transparent has since been almost completely reionized by UV starlight. With much improved signal-to-noise ratio, the *WMAP* V polarization data make it clear that the reionization took about half a billion years to complete. *WMAP* III had been consistent with much faster reionization. The polarization data also set a new upper limit on the cosmic gravity-wave background, a limit that begins to encroach on the range of candidate theories of inflation. And *WMAP* V resolves an incipient inconsistency: The fitted concordance-model parameters from *WMAP* III predicted a density-fluctuation amplitude for large-scale structure in the present cosmos that was two standard deviations lower than that determined from gravitational-lensing observations of the distribution of dark and ordinary matter. But now the *WMAP* V predictions are in good agreement with improved gravitational-lensing data. —BMS

Spin decoherence in diamond. An excellent heat conductor and electrical insulator, diamond is also a potential host for qubits—the units of quantum information that exist in a superposition of two different states. Previously demonstrated qubits include photons that can be in either of two polarization states, Cooper pairs that can reside on either side of a Josephson junction, and quantum dots with a net spin either up or down. In diamond, removing two neighboring carbon atoms and replacing one of them with a nitrogen atom results in a defect called a nitrogen–vacancy center. Such an NV center has a net electronic spin; can be optically imaged, polarized, and "read out"; and keeps its phase coherence for hundreds of microseconds at room temperature. A team of physicists from the University of California, Santa Barbara, and Ames Lab in Iowa, has now looked in detail at that coherence by watching an individual NV center interact with its environment—a local "spin bath" of randomly substituted nitrogen atoms in the diamond crystal. They found that the coupling between the NV center and the bath, and hence the center's decoherence time, could be finely tuned with an applied magnetic field. A rich variety of dynamical behavior could be accessed, including Rabi oscillations and a resonance "beating" phenomenon. (R. Hanson et al., *Science Express*, 13 March 2008, doi: 10.1126/science.1155400.) —PFS

Heralded pure single photons. If individual photons are to be harnessed for quantum information processing, they must not only be indistinguishable but also be in pure quantum states, not in incoherent mixed states. Creating such single photons is not easy, however. One of the most common approaches for generating individual photons involves nonlinear optics—four-wave mixing in optical fibers or three-wave mixing in crystals. But the resulting photons, produced in pairs, have spatial and temporal correlations that make them undesirable for scalable quantum information processing applications. Their suitability can be improved by using filters, but obtaining sufficient purity requires narrow filters that greatly slow the photon production rate and compromise the probability that detecting one photon of a pair reliably predicts the availability of its sibling. Now the University of Oxford's Ian Walmsley and colleagues have demonstrated that by choosing a nonlinear crystal with appropriate dispersion characteristics, they can sidestep those limitations and produce pairs of independent, pure photons through a process called parametric downconversion. The figure shows the calculated spectral distribution. Detecting one of the paired photons announces, or heralds, the presence of the other, yet in this case reveals nothing about its quantum state. Testing their heralded single photons by interfering the outputs from two independent sources, the researchers find a photon purity of 95% or higher, which they say should make the technique useful for future quantum-enhanced technologies. (P. J. Mosley et al., *Phys. Rev. Lett.* **100**, 133601, 2008.) —PFS ■